FIG. 1

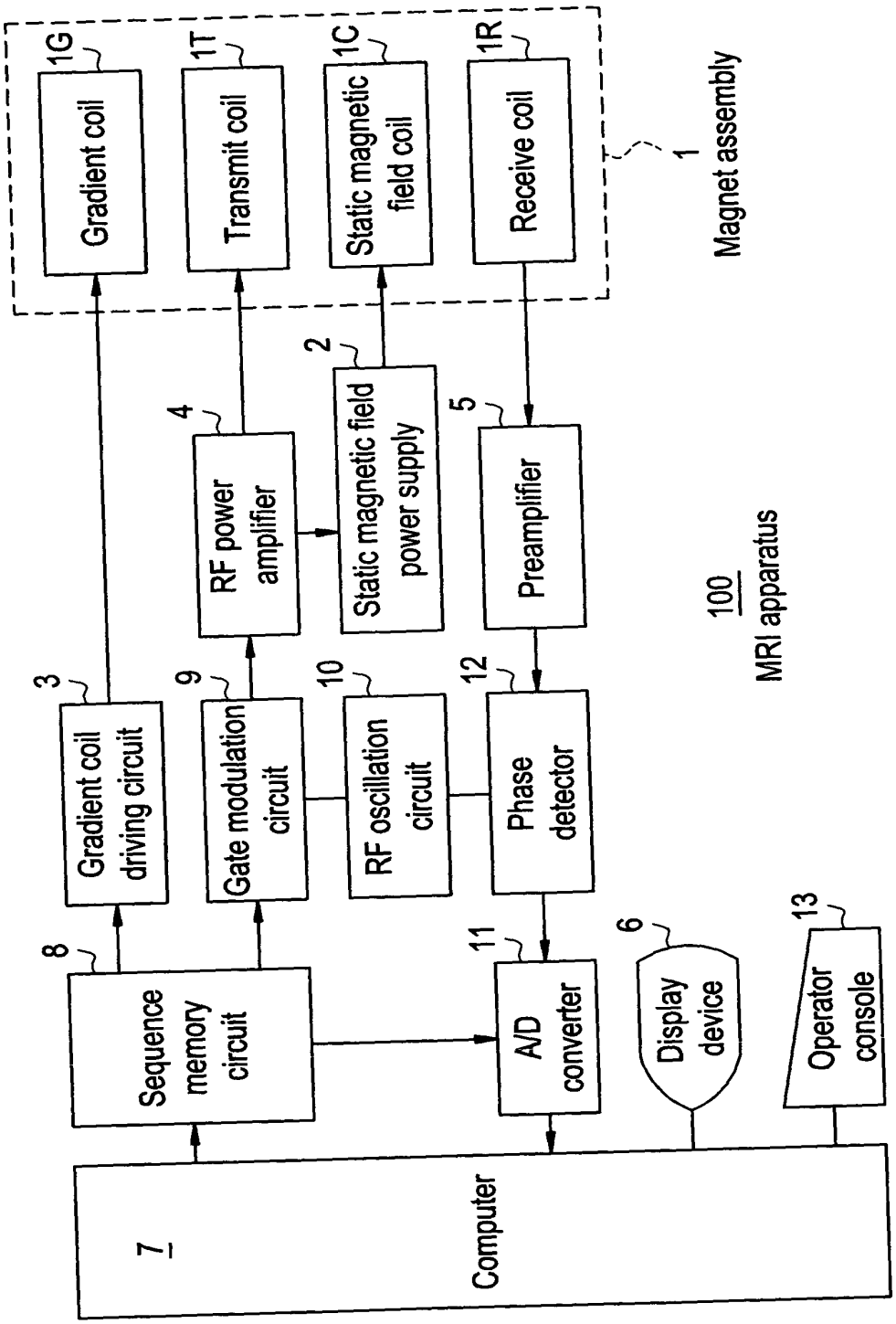
1G
Gradient coil
1T
Transmit coil
1C
Static magnetic field coil
1R
Receive coil
1
Magnet assembly
2
Static magnetic field power supply
4
RF power amplifier
5
Preamplifier
100
MRI apparatus
3
Gradient coil driving circuit
9
Gate modulation circuit
10
RF oscillation circuit
12
Phase detector
8
Sequence memory circuit
11
A/D converter
6
Display device
13
Operator console
7
Computer

FIG. 2

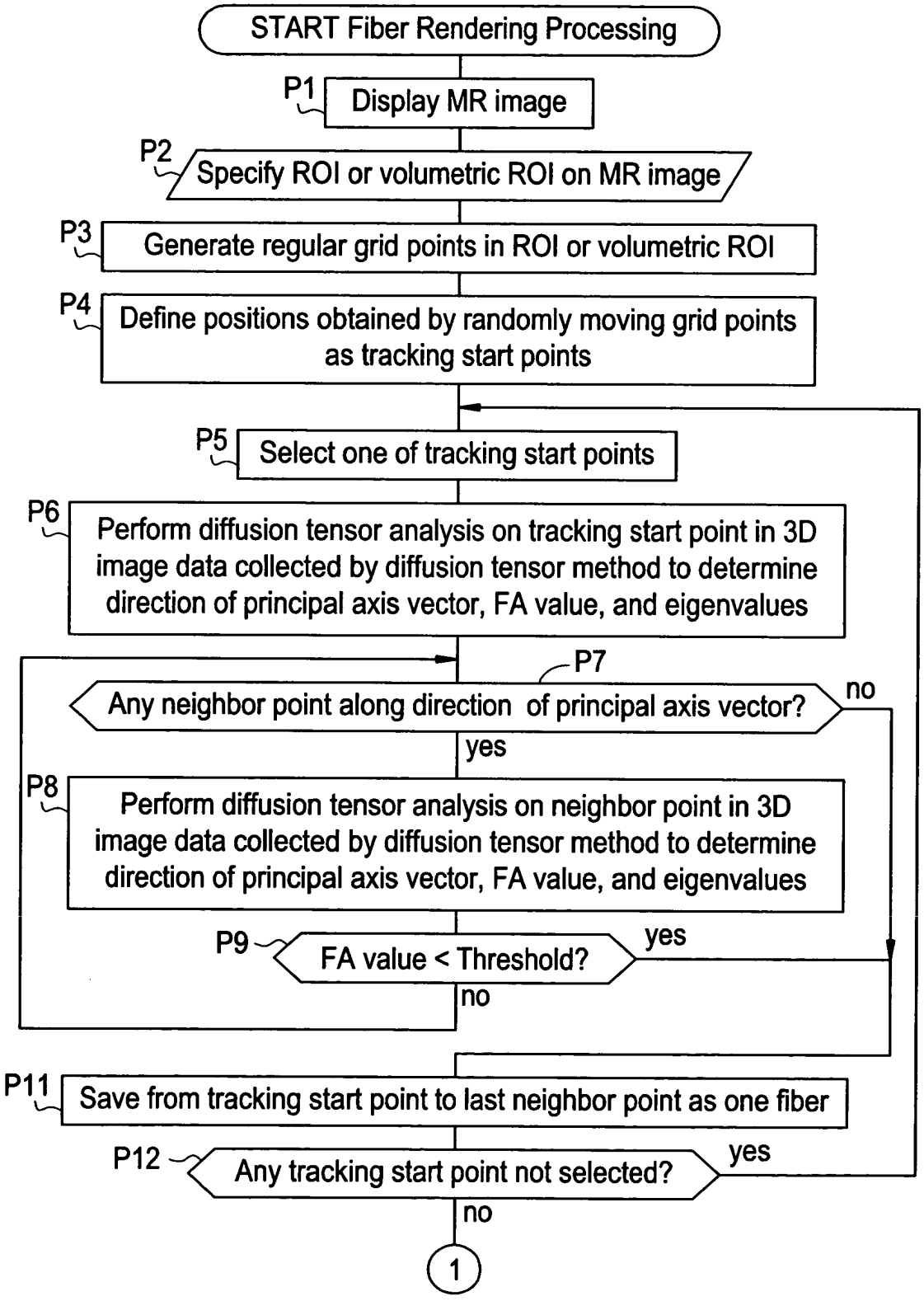
START Fiber Rendering Processing
P1
Display MR image
P2
Specify ROI or volumetric ROI on MR image
P3
Generate regular grid points in ROI or volumetric ROI
P4
Define positions obtained by randomly moving grid points as tracking start points
P5
Select one of tracking start points
P6
Perform diffusion tensor analysis on tracking start point in 3D image data collected by diffusion tensor method to determine direction of principal axis vector, FA value, and eigenvalues
P7
Any neighbor point along direction of principal axis vector?
no
yes
P8
Perform diffusion tensor analysis on neighbor point in 3D image data collected by diffusion tensor method to determine direction of principal axis vector, FA value, and eigenvalues
P9
FA value < Threshold?
yes
no
P11
Save from tracking start point to last neighbor point as one fiber
P12
Any tracking start point not selected?
yes
no
1

FIG. 3

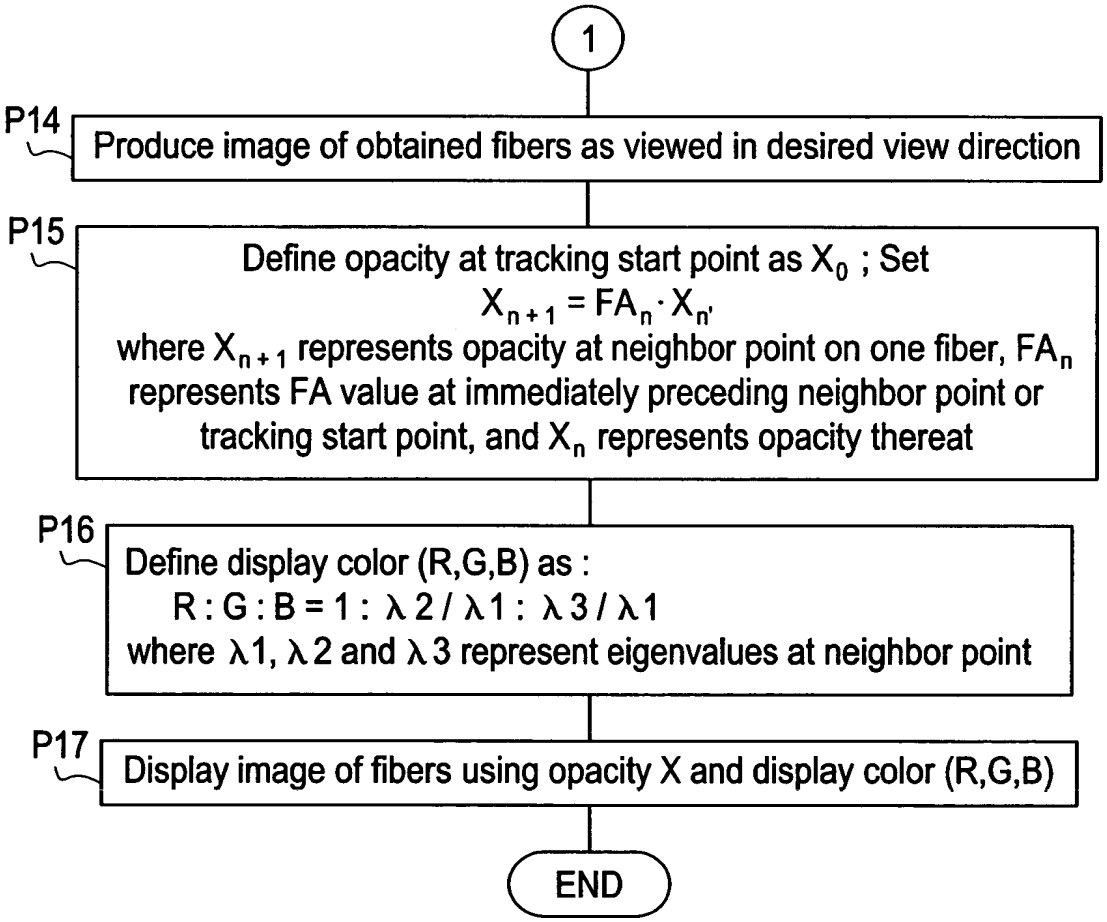
1
P14
Produce image of obtained fibers as viewed in desired view direction
P15
Define opacity at tracking start point as X_0 ; Set
$X_{n+1} = FA_n \cdot X_{n'}$
where X_{n+1} represents opacity at neighbor point on one fiber, FA_n represents FA value at immediately preceding neighbor point or tracking start point, and X_n represents opacity thereat
P16
Define display color (R,G,B) as :
R : G : B = 1 : λ2 / λ1 : λ3 / λ1
where λ1, λ2 and λ3 represent eigenvalues at neighbor point
P17
Display image of fibers using opacity X and display color (R,G,B)
END

FIG. 4

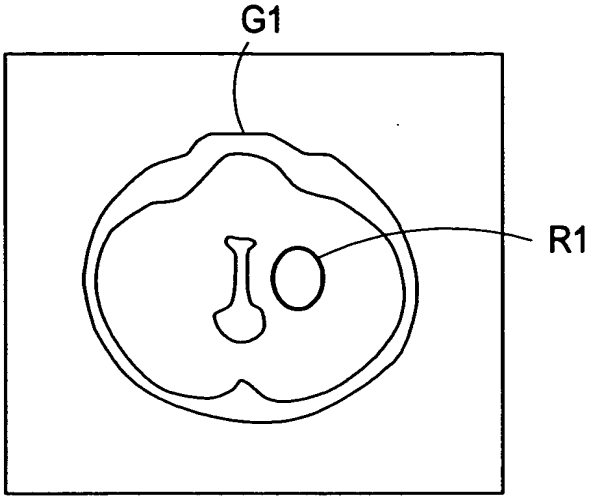

FIG. 5

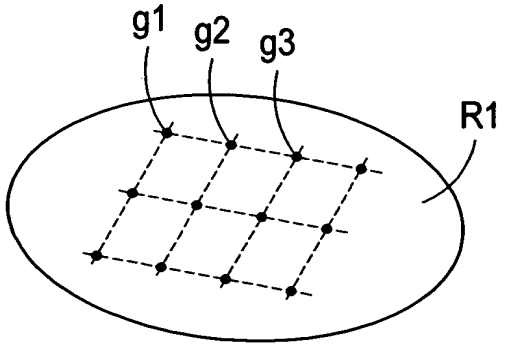

FIG. 6

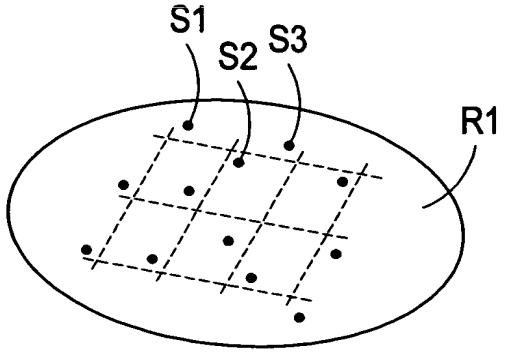

FIG. 7

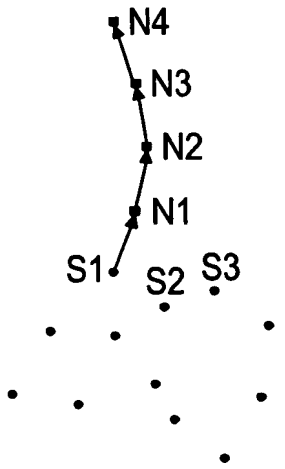

FIG. 8

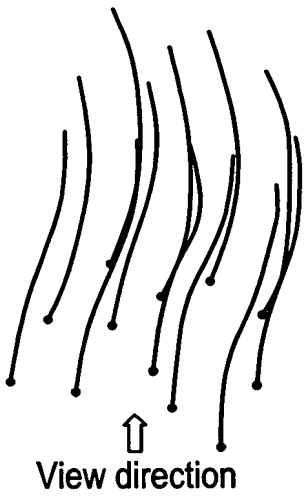

FIG. 9

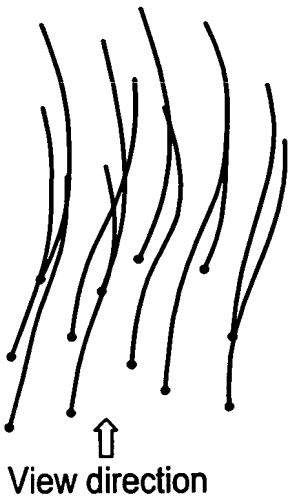

FIG. 10

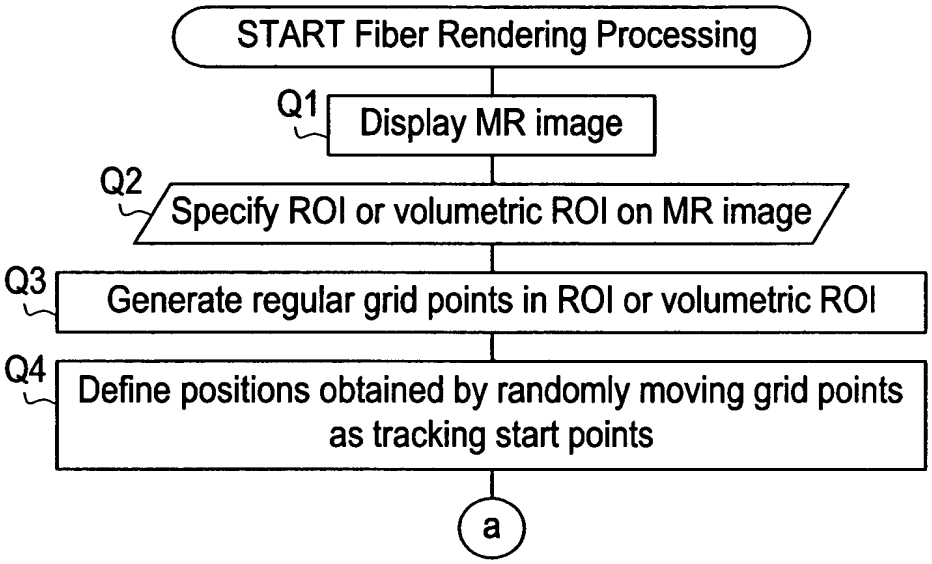
START Fiber Rendering Processing
Q1
Display MR image
Q2
Specify ROI or volumetric ROI on MR image
Q3
Generate regular grid points in ROI or volumetric ROI
Q4
Define positions obtained by randomly moving grid points as tracking start points
a

FIG. 11

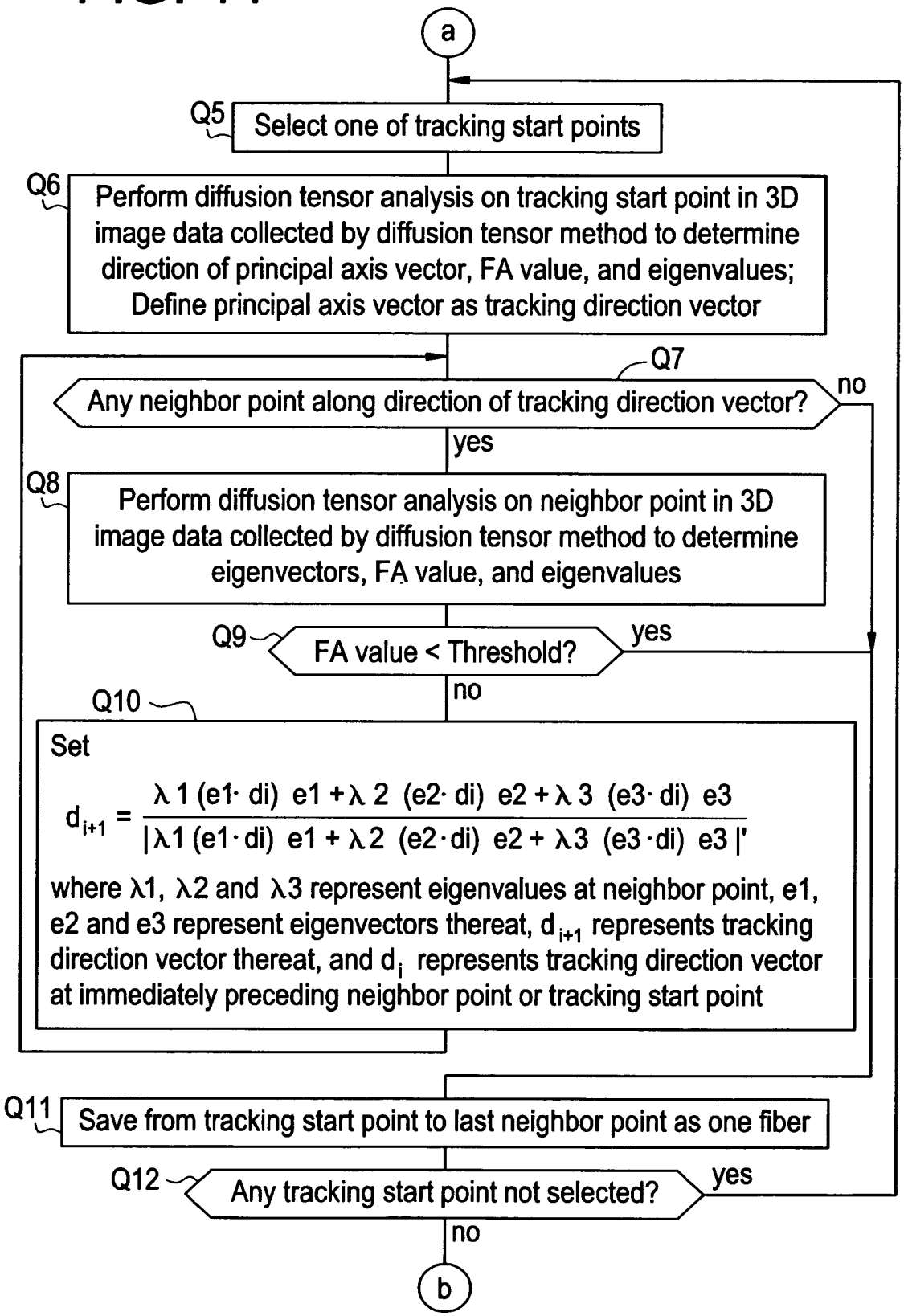
a
Q5
Select one of tracking start points
Q6
Perform diffusion tensor analysis on tracking start point in 3D image data collected by diffusion tensor method to determine direction of principal axis vector, FA value, and eigenvalues; Define principal axis vector as tracking direction vector
Q7
Any neighbor point along direction of tracking direction vector?
no
yes
Q8
Perform diffusion tensor analysis on neighbor point in 3D image data collected by diffusion tensor method to determine eigenvectors, FA value, and eigenvalues
Q9
FA value < Threshold?
yes
no
Q10
Set
$d_{i+1} = \frac{\lambda 1\,(e1\cdot di)\ e1 + \lambda 2\ (e2\cdot di)\ e2 + \lambda 3\ (e3\cdot di)\ e3}{|\lambda 1\,(e1\cdot di)\ e1 + \lambda 2\ (e2\cdot di)\ e2 + \lambda 3\ (e3\cdot di)\ e3\,|'}$
where λ1, λ2 and λ3 represent eigenvalues at neighbor point, e1, e2 and e3 represent eigenvectors thereat, d_{i+1} represents tracking direction vector thereat, and d_i represents tracking direction vector at immediately preceding neighbor point or tracking start point
Q11
Save from tracking start point to last neighbor point as one fiber
Q12
Any tracking start point not selected?
yes
no
b

FIG. 12

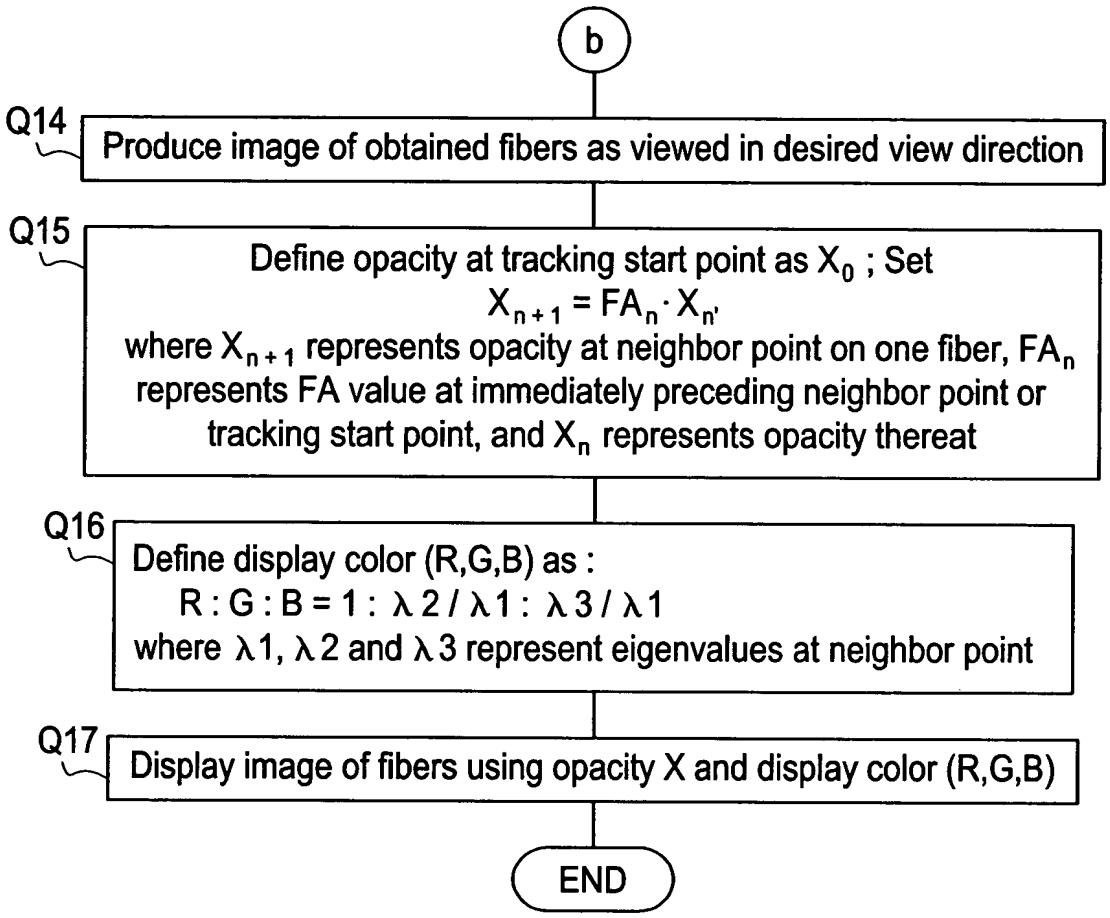
b
Q14
Produce image of obtained fibers as viewed in desired view direction
Q15
Define opacity at tracking start point as X_0 ; Set
$X_{n+1} = FA_n \cdot X_n$,
where X_{n+1} represents opacity at neighbor point on one fiber, FA_n represents FA value at immediately preceding neighbor point or tracking start point, and X_n represents opacity thereat
Q16
Define display color (R,G,B) as :
R : G : B = 1 : λ2 / λ1 : λ3 / λ1
where λ1, λ2 and λ3 represent eigenvalues at neighbor point
Q17
Display image of fibers using opacity X and display color (R,G,B)
END

FIG. 13

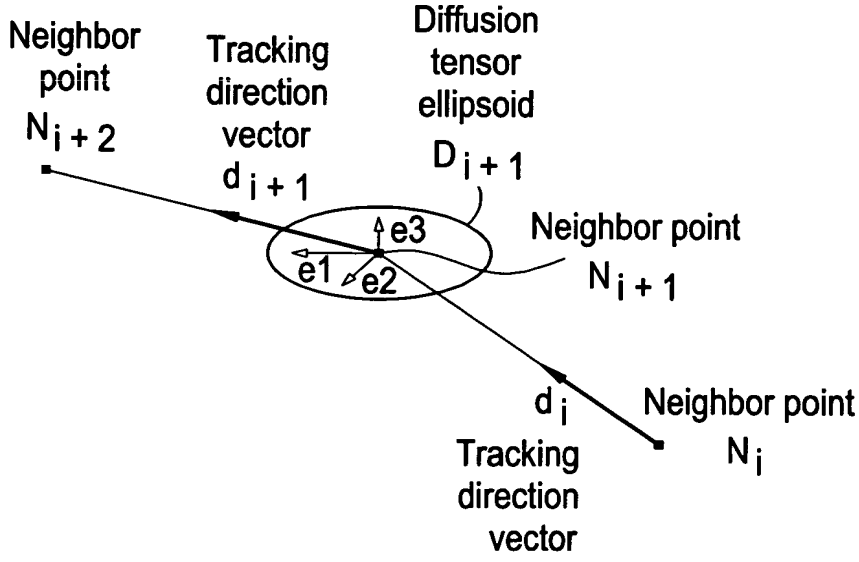
Neighbor point
N_{i+2}
Tracking direction vector
d_{i+1}
Diffusion tensor ellipsoid
D_{i+1}
e3
e1
e2
Neighbor point
N_{i+1}
d_i
Tracking direction vector
Neighbor point
N_i

FIG. 14

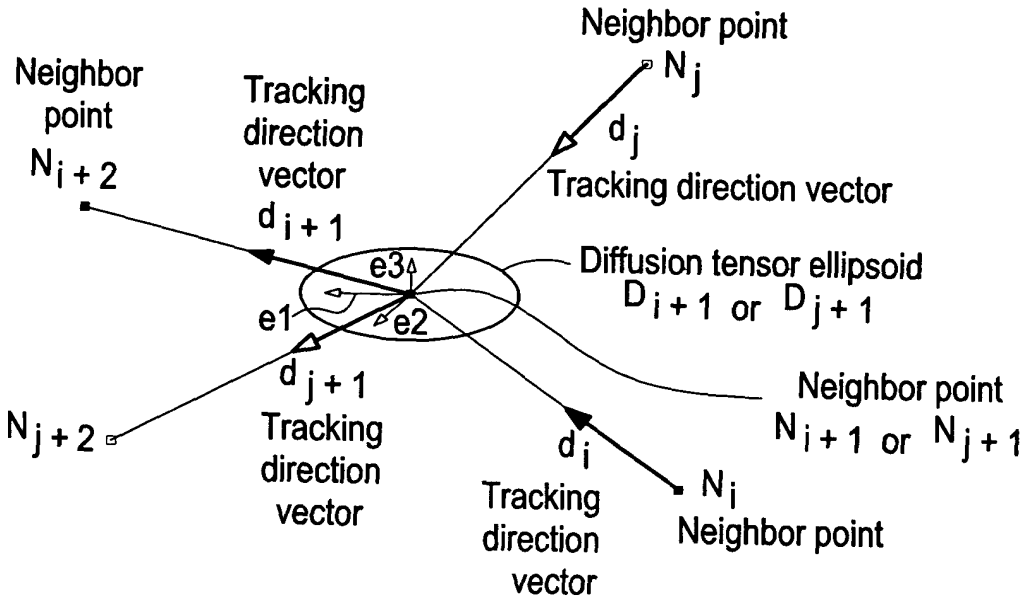
Neighbor point
N_j
d_j
Tracking direction vector
Neighbor point
N_{i+2}
Tracking direction vector
d_{i+1}
e3
Diffusion tensor ellipsoid
D_{i+1} or D_{j+1}
e1
e2
d_{j+1}
Tracking direction vector
N_{j+2}
Neighbor point
N_{i+1} or N_{j+1}
d_i
Tracking direction vector
N_i
Neighbor point

FIG. 15

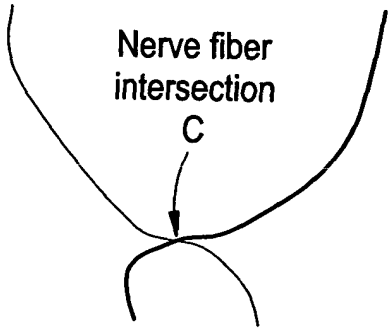
Nerve fiber intersection
C

FIG. 16

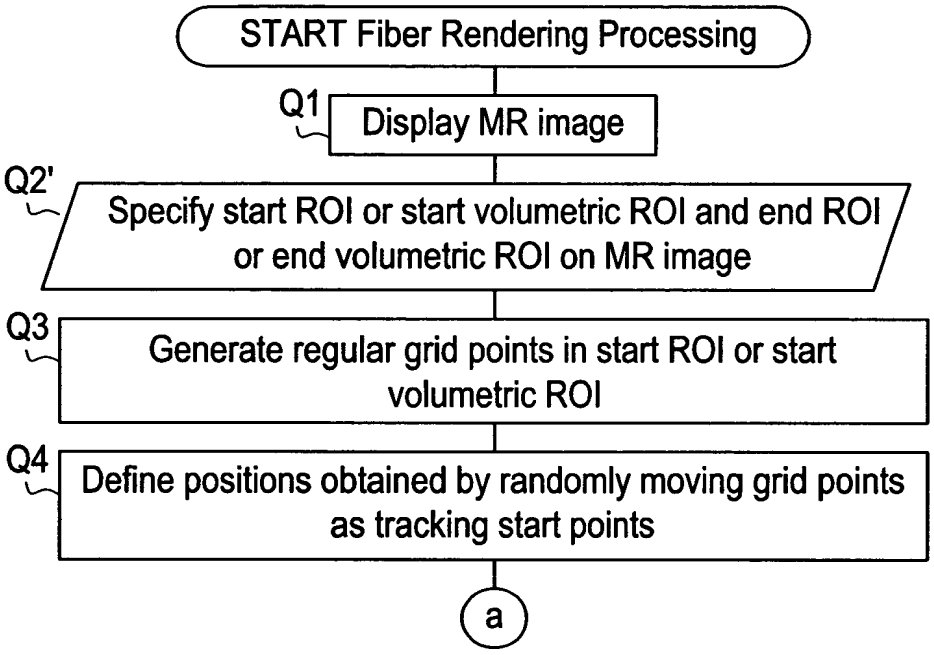
START Fiber Rendering Processing
Q1
Display MR image
Q2'
Specify start ROI or start volumetric ROI and end ROI or end volumetric ROI on MR image
Q3
Generate regular grid points in start ROI or start volumetric ROI
Q4
Define positions obtained by randomly moving grid points as tracking start points
a

FIG. 17

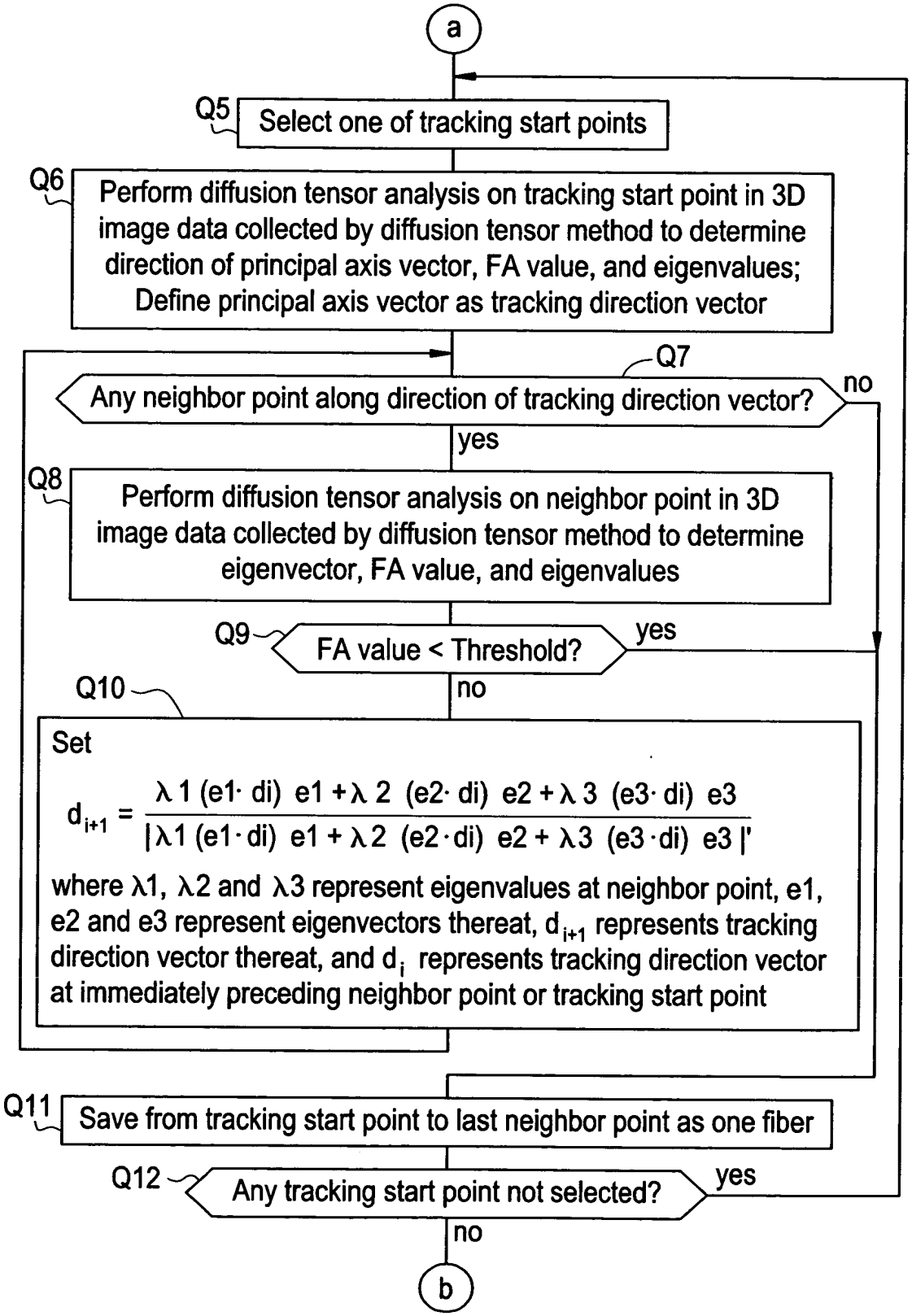
a
Q5
Select one of tracking start points
Q6
Perform diffusion tensor analysis on tracking start point in 3D image data collected by diffusion tensor method to determine direction of principal axis vector, FA value, and eigenvalues; Define principal axis vector as tracking direction vector
Q7
Any neighbor point along direction of tracking direction vector?
no
yes
Q8
Perform diffusion tensor analysis on neighbor point in 3D image data collected by diffusion tensor method to determine eigenvector, FA value, and eigenvalues
Q9
FA value < Threshold?
yes
no
Q10
Set
$d_{i+1} = \frac{\lambda 1\,(e1\cdot di)\ e1 + \lambda 2\ (e2\cdot di)\ e2 + \lambda 3\ (e3\cdot di)\ e3}{|\lambda 1\,(e1\cdot di)\ e1 + \lambda 2\ (e2\cdot di)\ e2 + \lambda 3\ (e3\cdot di)\ e3|'}$
where λ1, λ2 and λ3 represent eigenvalues at neighbor point, e1, e2 and e3 represent eigenvectors thereat, d_{i+1} represents tracking direction vector thereat, and d_i represents tracking direction vector at immediately preceding neighbor point or tracking start point
Q11
Save from tracking start point to last neighbor point as one fiber
Q12
Any tracking start point not selected?
yes
no
b

FIG. 18

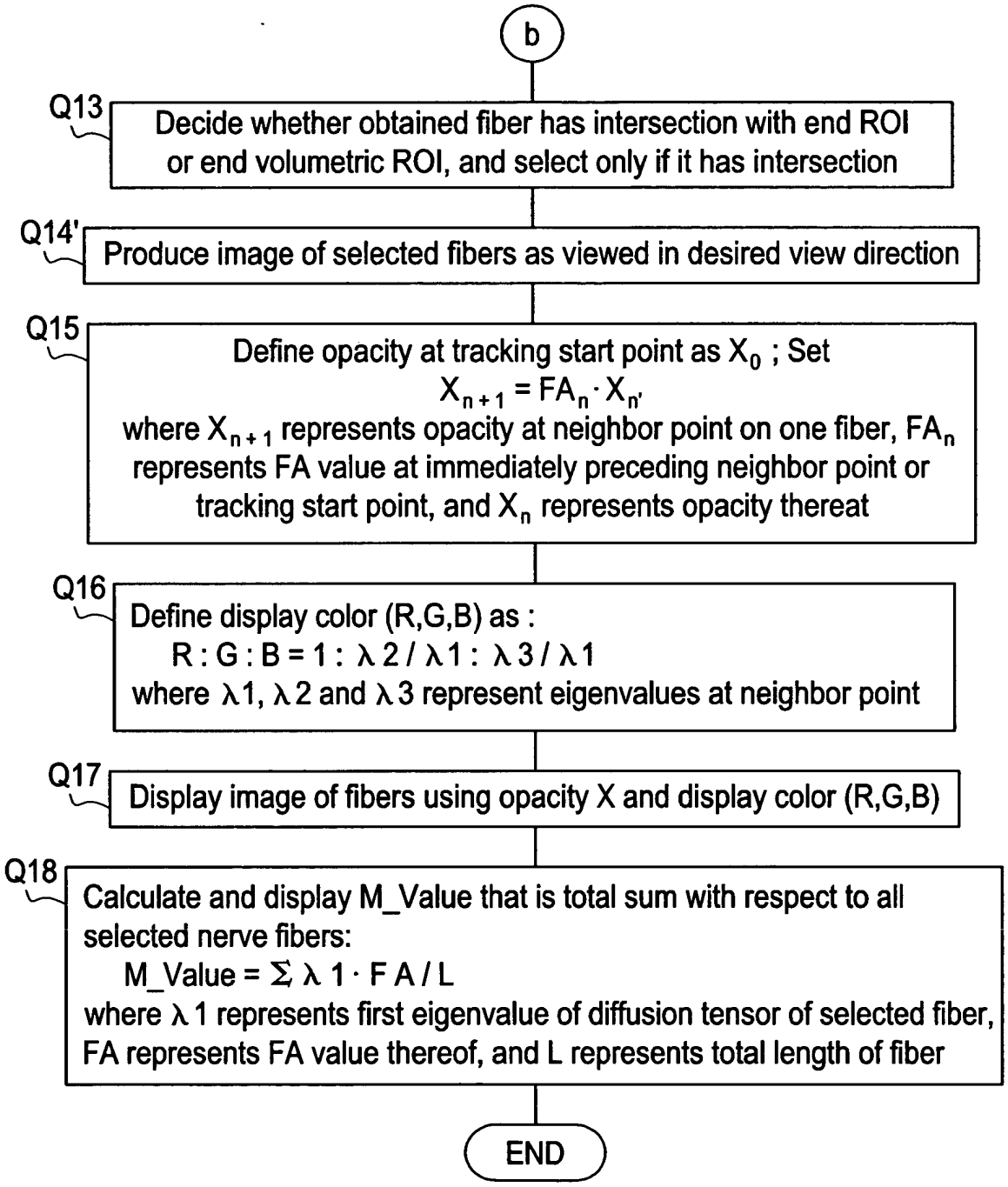
b
Q13
Decide whether obtained fiber has intersection with end ROI or end volumetric ROI, and select only if it has intersection
Q14'
Produce image of selected fibers as viewed in desired view direction
Q15
Define opacity at tracking start point as X_0 ; Set
$X_{n+1} = FA_n \cdot X_{n'}$
where X_{n+1} represents opacity at neighbor point on one fiber, FA_n represents FA value at immediately preceding neighbor point or tracking start point, and X_n represents opacity thereat
Q16
Define display color (R,G,B) as :
$R : G : B = 1 : \lambda 2 / \lambda 1 : \lambda 3 / \lambda 1$
where $\lambda 1$, $\lambda 2$ and $\lambda 3$ represent eigenvalues at neighbor point
Q17
Display image of fibers using opacity X and display color (R,G,B)
Q18
Calculate and display M_Value that is total sum with respect to all selected nerve fibers:
$M_Value = \Sigma \lambda 1 \cdot FA / L$
where $\lambda 1$ represents first eigenvalue of diffusion tensor of selected fiber, FA represents FA value thereof, and L represents total length of fiber
END

FIG. 19

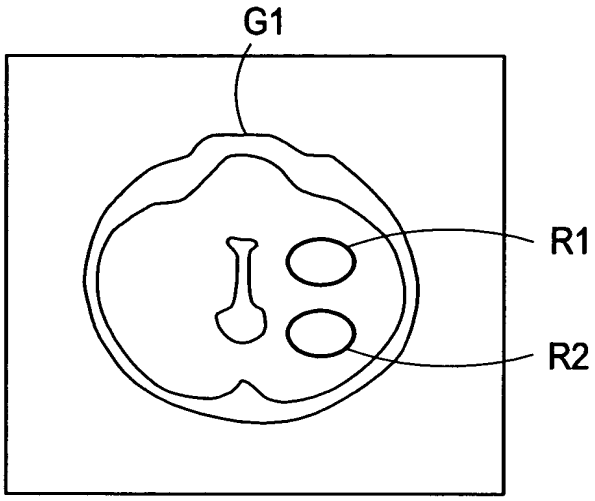

FIG. 20

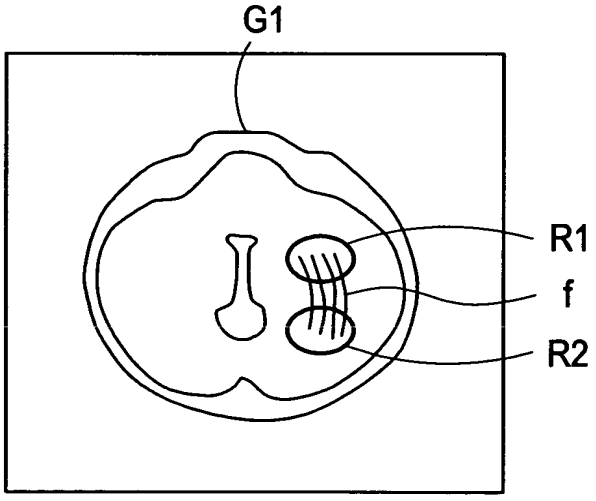

FIG. 21

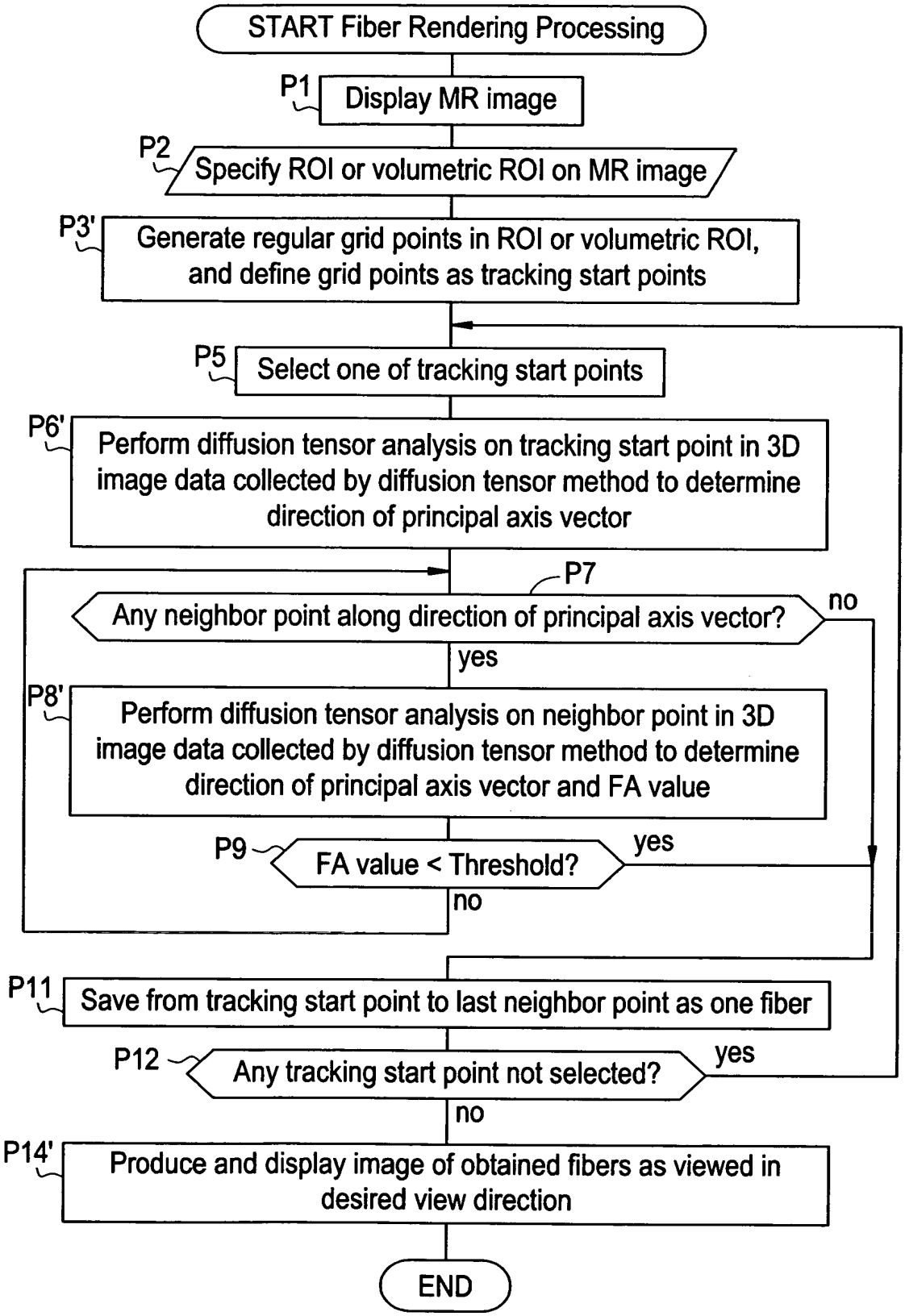
START Fiber Rendering Processing
P1
Display MR image
P2
Specify ROI or volumetric ROI on MR image
P3'
Generate regular grid points in ROI or volumetric ROI, and define grid points as tracking start points
P5
Select one of tracking start points
P6'
Perform diffusion tensor analysis on tracking start point in 3D image data collected by diffusion tensor method to determine direction of principal axis vector
P7
Any neighbor point along direction of principal axis vector?
no
yes
P8'
Perform diffusion tensor analysis on neighbor point in 3D image data collected by diffusion tensor method to determine direction of principal axis vector and FA value
P9
FA value < Threshold?
yes
no
P11
Save from tracking start point to last neighbor point as one fiber
P12
Any tracking start point not selected?
yes
no
P14'
Produce and display image of obtained fibers as viewed in desired view direction
END

FIG. 22

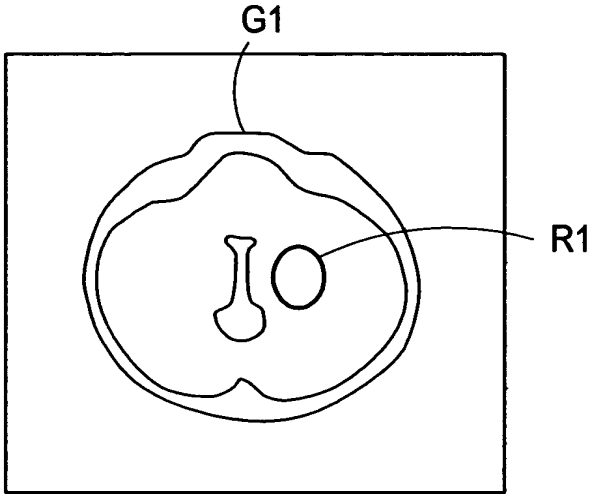

FIG. 23

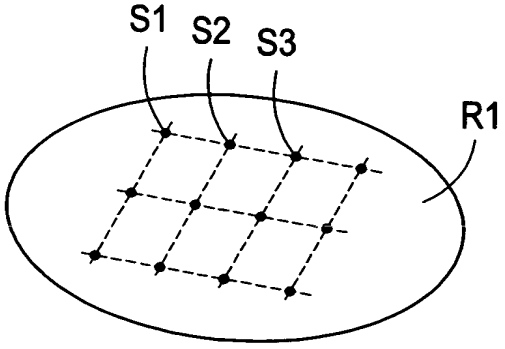

FIG. 24

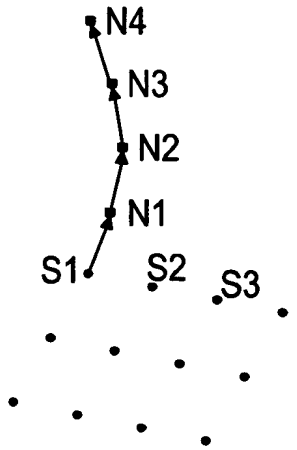

FIG. 25

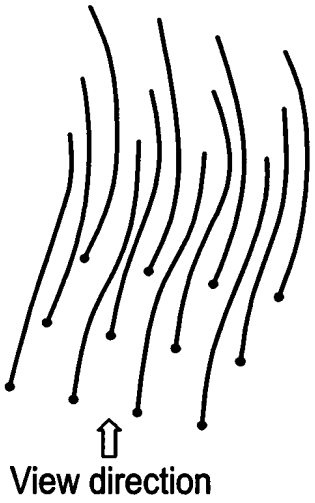

FIG. 26

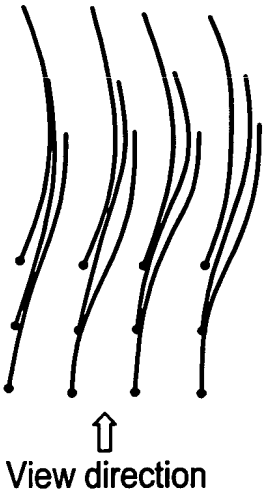

FIG. 27

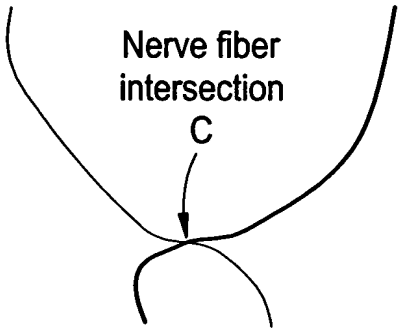
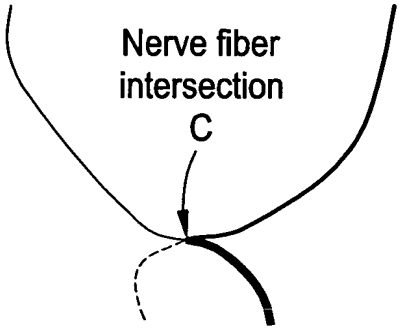
FIG. 28